An Asian Journal of Soil Science
Volume 11 | Issue 1 | June, 2016 | 37-42 | e ISSN–0976–7231 ■ Visit us : www.researchjournal.co.in

Research Article

DOI : 10.15740/HAS/AJSS/11.1/37-42

Impact of zinc on micronutrient content in root in different wheat cultivars

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Received : 25.01.2016; **Revised :** 19.03.2016; **Accepted :** 15.04.2016

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Summary

For the experiment, four different wheat varieties were selected of which two were Zn-efficient (GW190 and LOK-1) and two Zn-inefficient (GW399 and GW-403) varieties having three levels *viz.*, 0, 10 and 20 mg Zn kg^{-1} through zinc sulphate (21% Zn) with standard NPK fertilization. The cultivars were grown in pots (6, 7 and 10 kg capacity) upto three stages *viz.*, 20, 50 days after germination (DAG) and upto maturity. The experiment was laid out in a Factorial Completely Randomized Design (FCRD) and treatments were repeated thrice for all three stages. The varietal trend of root Zn content was observed in order as; GW399>GW403>GW190>LOK-1. The root Fe content was observed in order as LOK-1>GW190> GW399>GW403. The Mn content was observed as in order GW403>LOK-1> GW399>GW190. The varietal trend for root content Cu was found as in order GW190>GW403>LOK-1>GW399.

Key words : Wheat, Zn, Fe, Cu, Mn content, Root

How to cite this article : Kumar, Rajkishore, Ramani, V. P., Kumar, Rakesh, Kumar, Amarendra and Singh, Narendra (2016). Impact of zinc on micronutrient content in root in different wheat cultivars. *Asian J. Soil Sci.*, **11** (1) : 37-42 : **DOI : 10.15740/HAS/AJSS/11.1/37-42.**

Introduction

Zn deficiency was recorded in 49 per cent of the trials, with acute forms (with visible symptoms) noted in 25 per cent and hidden deficiencies confirmed by yield responses to Zn amendments noted in 24 per cent (Sillanpaa, 1990). It is estimated that approximately 50 per cent of soils used for cereal production in the world have low levels of plant-available Zn (Graham and Welch, 1996). Zinc (Zn) deficiency is the most widespread micronutrient deficiency in agricultural lands around the world, causing yield decreases and diminishing the nutritional quality of agricultural plants. Plant-based foods are significant sources of Zn for humans (Welch and Graham, 2004). Zinc is one of the eight trace elements (manganese, copper, boron, iron, zinc, chlorine, molybdenum and nickel) that are essential for normal, healthy growth and reproduction of plants. Zn is required as a structural component of a large number of proteins, such as transcription factors and metalloenzymes (Figueiredo *et al.*, 2012). If an insufficient amount of Zn

is available, the plants will suffer from physiological stresses due to the failure of metabolic processes in which Zn plays a critical role. Zinc efficiency can be influenced by root morphology, which varies among plant species (Dong *et al*., 1995). Longer and thinner roots with increased root surface area may influence the availability of Zn and other nutrients, such as Cu, Mn and Fe (Rengel and Graham, 1995). Roots alter the rhizosphere chemistry by changing the rhizosphere pH (Wang *et al*., 2006) and/ or releasing PS that can chelate soil Zn and increase its availability (Cakmak *et al*., 1994). The root-mediated decrease in pH increases Zn availability by solubilizing Zn present in inorganic and organic soil complexes (Hacisalihoglu *et al.*, 2003). Compared with Zn-inefficient genotypes, Zn-efficient genotypes can deliver more Zn from roots to shoots under low Zn conditions but not under Zn-sufficient conditions (Rengel and Graham, 1995 and Cakmak *et al*., 1996a). Zn reaches the plant root surface through mass flow, diffusion and root interception mechanisms.

Mass flow is passive nutrient transport from the soil to the roots and is driven by transpiration. When the solution moving through the soil to the root contains a relatively large concentration of Zn, mass flow becomes the dominant mechanism bringing Zn to the root surface. When the Zn concentration is low, particularly in soils with low plant-available Zn, diffusion plays important role in the transport of Zn and other nutrients, such Cu, Fe and Mn, to the root surface because mass flow can only carry a small fraction of the nutrients required by the plants. The root interception (*i.e.*, root growth and root surface area) is also an important factor in determining plant availability of Zn. Hence, present study was planned regarding Zn transport from the soil to the root and amount of nutrient present in root in different wheat cultivars which play an important role in differential Zn efficiency.

Resource and Research Methods

Present investigation was conducted during *Rabi* season of 2012 in the net house of Micronutrient Project (ICAR), Anand Agricultural University, Anand. A pot culture experiments was conducted to determine Zn uptake by different wheat varieties which were Zn-efficient GW190, LOK-1 and Zn in-efficient variety GW399, GW403, respectively, The soil is representative of the soils of the middle Gujarat region and is locally known as “Goradu” soil. The texture of the soil is loamy sand, belongs to the soil order *Inceptisoils* (*Typic Ustochrepts*). A pot house experiment conducted in modern laboratory of Micronutrient project, BACA, AAU, Anand having soil with loamy sand character, pH (1:2.5)- 7.2, 5.12 per cent clay, 10.47 silt and 0.34 per cent organic carbon. The soil having pH 7.2, EC 0.14 method followed by Jackson (1967). But in respect of available Zn (0.43 mg/kg) and Fe (4.9 mg/kg) method followed by Lindsay and Norvell (1978). The soil of the experimental pot was found deficient in nature which was needed for investigation programme. In case of fertilizer, urea used as a nitrogen source, potassium di-hydrogen phosphate used as phosphorus and zinc applied through Zn sulphate (21% Zn). In order to evaluate the Zn efficiency of wheat varieties, three levels of Zn were kept *viz.*, i) Control (Zn0), ii) 10 mg/kg Zn soil (Zn10) and iii) 20 mg/kg Zn soil (Zn20). In *Rabi* season, eighteen, nine and six seeds were planted into the 6 kg, 7 kg and 10 kg capacity pots, respectively for stage (1 harvest at 20 DAG), stage 2 harvest (50 DAG) and stage 3 harvest at maturity stage.

Statistical analysis :

The data, collected for all the characters involved under study were subjected to the statistical scrutiny (analysis) for proper interpretation. The standard method of analysis of variance technique appropriate to the Factorial Complete Randomized Design (FCRD) described by Panse and Sukhatme (1967) was used.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Zinc (Zn) content :

The influence of Zn application, growth stages and varieties on Zn concentration of plant at different growth stages of different wheat cultivars. The individual effects of Zn application, varieties and growth stage found significant. The combined effect of all these parameters was also affected Zn content in wheat shoot. The varietal trend of root Zn content was observed in order as; GW399>GW403>GW190>LOK-1 (Table 1). Here, R^2 value indicates 44, 4 and 0.1 per cent in 20, 50 DAG and at maturity stage, respectively. The significantly highest Zn content was found at 20 DAG and showed decreased in further increase in growth stages. After root elongation

(growth stage increases), Zn concentration fell, it may be due to rapid structural growth and dilution effect of concerned element (Fig.1). Similar results were also reported by Hebbern *et al*. (2005) in case of Mn in barley crop. Hence, Zn-efficient genotypes could reduce land degradation by limiting the use of machinery and minimizing fertilizer inputs on agricultural lands. Zn-efficient cultivars of wheat, barley and rice are available (Gregorio *et al*., 2000; Genc and McDonald, 2004) and are grown quite widely in soils with low levels of available Zn. Similar results have also been reported in wheat genotypes under Zn efficiency by Khoshgoftarmanesh *et al*. (2006). It might be due to efficient varieties had a low rate of organic acid exudation than the inefficient genotypes. This observation is also in agreement for maize while screening for P efficiency under P – stress condition (Liu *et al*., 2004). Hence, increasing the Zn content of staple crops will enhance the intake of bioavailable Zn and improve the Zn status of deficient populations (Biesalski, 2013).

Iron (Fe) content :

There was significant influence of Zn on Fe concentration in shoot and root at different growth stages as shown in Table 1. The root Fe content was observed in order as LOK-1> GW190> GW399>GW403. Here,

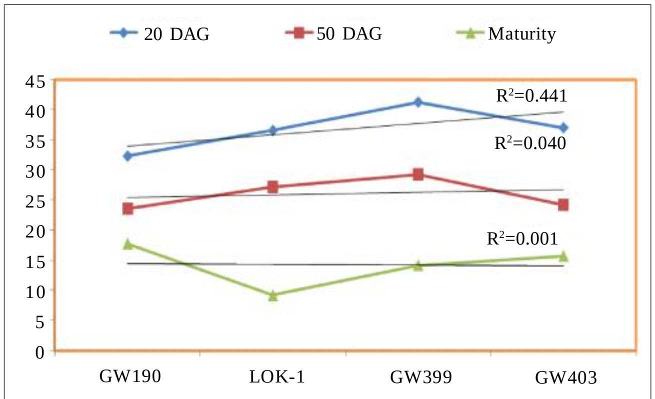

Fig. 1 : Effect of different treatments on Zn content in root of different wheat cultivars

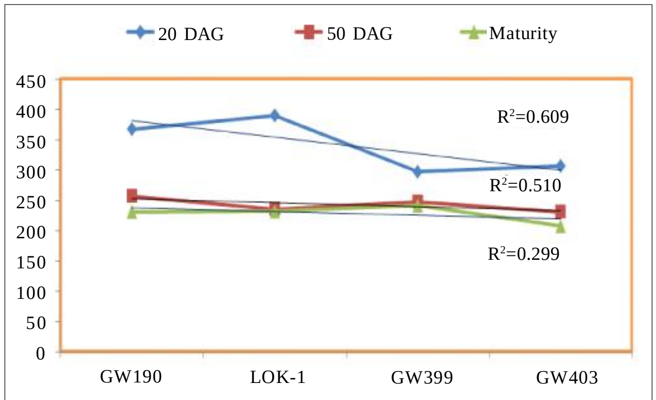

Fig. 2 : Effect of different treatments on Fe content in root of different wheat cultivars

Table 1: Influence of Zn application in different micronutrients content in root of wheat cultivars

Zn levels	Zn (ppm)			Fe (ppm)			Mn (ppm)			Cu (ppm)		
	20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity
Control	26.07	16.65	12.31	355.88	257.51	256.44	37.14	27.11	12.74	14.16	5.60	3.10
10 ppm	39.83	25.00	14.13	336.03	247.12	219.89	38.54	28.51	13.70	18.73	5.88	4.11
20 ppm	44.37	36.44	16.26	329.88	224.95	213.03	30.52	26.80	13.54	17.81	5.55	3.36
Variety												
GW190	32.25	23.50	17.79	367.74	256.64	230.92	29.22	23.98	14.01	19.46	6.44	4.44
LOK-1	36.53	27.18	9.20	390.26	235.69	231.17	39.83	30.81	11.12	16.93	5.55	4.18
GW399	41.26	29.24	14.20	297.33	247.98	241.11	32.51	23.97	15.46	12.72	5.99	3.61
GW403	36.99	24.20	15.74	307.06	231.05	207.35	40.04	31.12	12.72	18.49	4.71	4.54
	S.E.(±)	C. D.(P=0.05)		S.E.(±)	C. D. (P=0.05)		S.E.(±)	C.D. (P=0.05)		S.E.(±)	C. D. (P=0.05)	
Stage	0.70	1.95		4.90	13.79		0.45	1.25		0.22	0.61	
Variety	0.80	2.25		5.650	15.93		0.52	1.45		0.25	0.71	
Zn	0.70	1.95		4.90	13.79		0.45	1.25		0.22	0.61	
S x V	1.38	3.90		9.79	27.59		0.89	2.51		0.44	1.23	
S x Zn	1.12	3.38		8.474	NS		0.77	2.17		0.38	1.06	
V x Zn	1.38	NS		9.79	NS		0.89	2.51		0.44	NS	
S x Zn x V	2.34	NS		16.95	NS		1.54	4.34		0.76	NS	
CV (%)	16.18			10.82			10.5			14.64		

Note- Zn-efficient Variety-GW403 and LOK-1, Zn-inefficient Variety-GW403 and LOK-1 NS=Non-significant

R^2 value indicates 60, 51 and 29 per cent in 20, 50 DAG and at maturity stage, respectively. The results indicated that Zn efficient verity give more response of Fe compared to Zn inefficient variety at successive growth stage. The highest Fe content was found at 20 DAG and showed decreased in further increase in growth stage. After root elongation (growth stage increases), Fe concentration fell, it may be due to rapid structural growth and dilution effect of concerned element (Fig. 2). Similar results were reported by Hebbern *et al.* (2005) in case of Mn in barley crop and Edwards and Barber (1976) in case of P. Total content of Fe in shoots between efficient and inefficient varieties did not differed much upto second growth stage. Therefore, the results also indicated that concentration of Fe in plant tissues is not being considered as a reliable parameter for distinguishing of genotypes (Cakmak *et al*. 1996b). However, it was noticed that at maturity stage efficient accumulates lower Fe content than inefficient varieties; the observation in agreement with that observed by Graham *et al*. (1992).

Manganese (Mn) content :

The application of Zn, varieties and growth stages had a significant effect on root Mn content was observed as in order GW403>LOK-1>GW399>GW190 (Table 1). Here, R^2 value indicates 36, 21 and 0.1 per cent in 20, 50 DAG and at maturity stage, respectively (Fig.3). In case of Mn, In-efficient varieties significantly influenced on Mn content of the elements in shoots and root compared to efficient variety because of their differential absorption and solublize capacity of these metal nutrients higher in inefficient variety and also have fewer accumulators of Mn and Zn in shoots which could be mainly due to better capacity of exploring a large volume of soil by inefficient varieties to facilitate higher absorption of Mn. Efficient wheat genotypes are heavy producer of organic acid especially citric acid, which are highly effective in chelating Mn under deficient conditions. In case of growth stages, the plant content of these nutrients upto second growth stage and, thereafter, in decreased due to dilution effect of nutrient in shoots. The significantly highest Mn content was found at 20 DAG and showed decreased in further increase in growth stages. After stem elongation (growth stage increases), Zn concentration fell, it may be due to rapid structural growth and dilution effect of

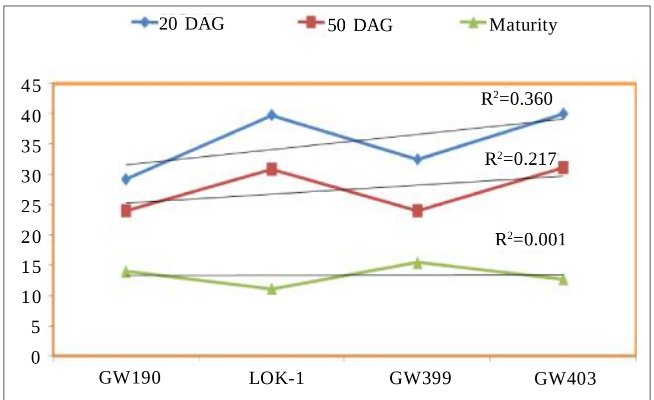

Fig. 3 : Effect of different treatments on Mn content in root of different wheat cultivars

Table 2: Simple correlation between micronutrient content in root and 20, 50 DAG and maturity stage of different wheat cultivars

		Zn (ppm)			Fe (ppm)			Mn (ppm)			Cu (ppm)		
		20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity	20 DAG	50DAG	Maturity
Zn	20 DAG	1											
(ppm)	50DAG	0.9136	1										
	Maturity	0.2029	0.2107	1									
Fe	20 DAG	-0.4925	-0.2830	-0.4505	1								
(ppm)	50DAG	-0.6925	-0.7271	0.0103	0.2344	1							
	Maturity	-0.6521	-0.5522	-0.4227	0.2963	0.7625	1						
Mn	20 DAG	-0.1875	-0.4085	-0.6562	0.0954	-0.1743	-0.0880	1					
(ppm)	50DAG	0.0188	-0.0942	-0.4945	0.1684	-0.5532	-0.4399	0.8740	1				
	Maturity	0.3252	0.2270	0.6181	-0.6610	0.3193	0.0926	-0.6516	-0.8127	1			
Cu	20 DAG	0.1283	0.1150	0.4294	0.2763	-0.2805	-0.7284	0.0044	0.3156	-0.2813	1		
(ppm)	50DAG	-0.0899	-0.0057	0.19448	0.3084	0.6559	0.4449	-0.6574	-0.7981	0.5029	-0.0533	1	
	Maturity	0.0707	-0.0737	0.20289	0.1114	-0.1134	-0.5512	0.2388	0.3390	-0.1848	0.6803	-0.0907	1

•DAG- Days after germination ** and *** indicate significance of values at P=0.05 and 0.1, respectively

concerned element (Fig. 3). Similar results were also reported by Hebbern *et al*. (2005) in case of Mn in barley crop and Edwards and Barber (1976) in case of P.

Copper (Cu) content :

In case of Cu, efficient varieties significantly influenced on root Cu content and as in order GW190>GW403>LOK-1>GW399. Here, R^2 value indicates 9, 69 and 0.7 per cent in 20, 50 DAG and at maturity stage, respectively (Fig. 4). The maximum variation found at maturity stage and overall results indicated that application of Zn, Zn -efficient variety give more response compared to Zn in-efficient variety. Efficient wheat genotypes are heavy producer of organic acid especially citric acid, which are highly effective in chelating with Cu under Zn deficient conditions (Fig.4). Similar results have been reported by Cakmak *et al*. (1997) in rye under Zn deficient soil and in wheat genotypes under Zn efficiency (Khoshgoftarmanesh *et al*., 2006). It might be due to efficient varieties had a low rate of organic acid exudation than the inefficient genotype. This observation is in agreement with Liu *et al*. (2004) for maize while screening for P efficiency.

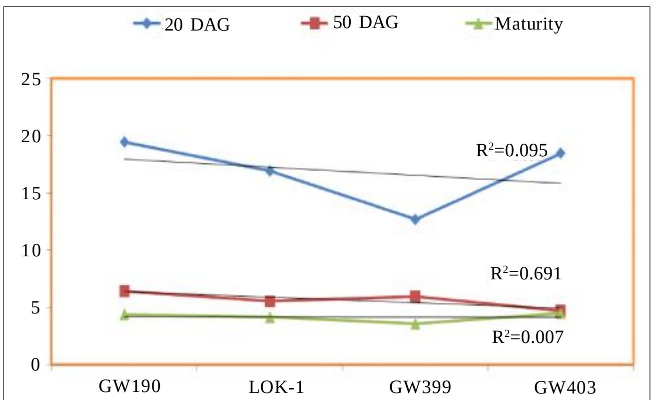

Fig. 4 : Effect of different treatments on Cu content in root of different wheat cultivars

It can be amply surmised from the available literature that zinc efficiency of cereals under zinc deficiency is regulated by several factors, most importantly, Zn application was less on Zn efficient varieties may be due to lower internal Zn requirement, under Zn stress condition, in absence of Zn application it is better to grow Zn efficient verities while the application of Zn @ 20 mg kg^{-1} on Zn deficient soil is beneficial for better growth and development of Zn inefficient wheat varieties besides better Zn content in plant.

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